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RESEARCH ARTICLE

Towards achieving environmental sustainability: environmental quality versus economic growth in a developing economy on ecological footprint via dynamic simulations of ARDL

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Abstract

Studies have shown that factors like trade, urbanization, and economic growth may increase the ecological footprint (EFP) since ecological distortions are mainly human-induced. Therefore, this study explores the effect of economic growth and urbanization on the EFP, accounting for foreign direct investment and trade in Nigeria, using data from 1977 to 2016. This study used the EFP variable as against the CO_2 emissions used in the previous studies since the former is a more comprehensive and extensive measure of environmental quality. We apply the novel dynamic autoregressive distributed lag (ARDL) simulations for model estimation, the Bayer and Hanck J Time Ser Anal 34: 83–95, (2013) combined cointegration, and the ARDL bounds test for cointegration. Although the results affirmed the presence of long-run relationship among the variables, economic growth deteriorates the environment in the short run, while urbanization exacts no harmful impact. In the long run, FDI and trade deteriorate the environment while economic growth adds to environmental quality. It is recommended that policymakers strengthen the existing environmental regulations to curtail harmful trade and provide rural infrastructures to abate urban anomaly.

Keywords Economic growth · Urbanization · Trade · FDI · Ecological footprint · Nigeria

JEL classification O13 · Q32 · Q43

Abbreviations

ADF Augmented Dickey–Fuller
PP Phillips–Perron
ZA Zivot and Andrews

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BH	Bayer and Hanck
ADRL	Autoregressive distributive lag
DADRL	Dynamic autoregressive distributive lag
GHG	Greenhouse gas
CO	Carbon monoxide
CO_2	Carbon dioxide
GDP	Gross domestic product
ECT	Error correction term
FDI	Foreign direct investment
OLS	Ordinary least square
UN	United Nations
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
UECM	Unrestricted error correction model
AIC	Akaike information criterion
SIC	Schwarz information criterion
HQ	Hannan Quinn information criterion
FPE	Final prediction error

Introduction

The relationship between economic growth and climate change is one that creates a paradox. As the world leaders have committed to the 2030 Sustainable Development Goals (SDGs), how Nigeria seeks to ensure economic growth without contributing to the existing seemingly damaged condition of the climate should be of great concern to the policymakers. The concentrated efforts to promote the industrialization of the urban areas have contributed greatly to rural-urban migration in Nigeria. Though the rural areas are not industrialized, the amount of carbon released into the atmosphere as a result of the burning of woods for cooking as well as the exposure of farmland to the harsh weather is also adversely affecting the status of the climate. As a signatory to the United Nations SDGs with climate-related goals 7 and 13, Nigeria as one of the most populous developing countries needs to make efforts to achieve economic growth without causing damage to the environment.

The relationship among population growth, urbanization, and CO_2 emissions around the globe and especially in developing nations has attracted the attention of researchers, stakeholder and policymakers (see, for instance, Alola et al. 2019a; Akadiri et al. 2019; Nathaniel et al. 2020c, 2020d; Dogan 2014). With population growth comes the need for the citizens to search for greener pasture. This leads to rural-urban migration and consequent growth in the urban population (urbanization) as well as an increase in production activities to meet the needs of the people. Consequently, the emission of greenhouse gases becomes inevitable (Nathaniel and Iheonu 2019). While it is projected by the United Nations that 64% of the developing nations will be urbanized by 2050, now, half of the global citizens live in the urban centers (Shahbaz et al. 2016). Urbanization has witnessed a rapid increase in Asia and Africa. On a global scale, it is being estimated to rise to 4.6 billion by 2030. However, the bulk of these people are expected to be in African and Asian cities.

The planet system is normally expected to regulate the emissions of CO_2 in the space; the large emissions of this gas have rendered the planet inefficient (Nathaniel et al. 2019) . The rise in CO_2 emissions directly affects the human race and indirectly on what the human race depends upon such as agriculture, climate, and weather. According to IEA (2017), China with about 29.4% of the global emissions of CO_2 is the highest contributor, while the USA, the second-highest contributor, contributes about 14.3%, European Economic Area, India, Russia, Japan, and others (including Africa) contribute 9.8%, 6.8%, 4.9%, 3.5%, and 31.5% in 2016. The effects of climate change in Africa is largely negative and far-reaching. They impede generally on agriculture and hence the food security status of the continent. Some of these effects, according to Atif and Mohammed (2017), include rising temperature leading to soils drying up, an increase in pest infestation and disease outbreaks, floods, and erosions among others.

Anxiety over the impact of CO_2 emissions on the human race has led researchers to conduct findings to establish whether or not the environmental Kuznets curve (EKC) exists for CO_2 emissions. Nigeria has an active population of about 182 million people (National Population Commission 2017). Although this is good for the developing nation, it may increase the industry-induced carbon emissions which can further degrade the already-changing climatic condition of the entire universe. So, how can Nigeria grow in the midst of perceived heavy industrialization of her economic space without further endangering the ecosystem? In what way(s) can the economy of Nigeria grow within a sustainable environmental space? The study provides answers to these questions.

This is the first study to use ecological footprint (EFP) as a measure for environmental degradation in the growth-environment nexus studies for Nigeria. Previous studies (see Cosmas et al. 2019; Ali et al. 2016; Rafindadi 2016; Lin et al. 2015; Nathaniel et al. 2020e) that considered Nigeria used CO_2 emissions. EFP is an aggregate indicator (Wang & Dong 2019; Hassan et al. 2019) that performs better than CO_2 emissions (Alola et al. 2019b; Charfeddine 2017; Dogan et al. 2019). The EFP is a more comprehensive measure for pollutant emissions compared to CO_2 emissions which are widely used in the existing literature (Katircioglu et al. 2018; Bello et al. 2018). The EFP is a distinctive proxy for environmental quality that accounts for other natural areas that are essential for economic growth. The natural areas captured by EFP includes the availability of water resources, arable farmland and freshwater, forest reserves, and fresh air. The availability of the outlined natural areas and their ability to support life and the ecosystem are supported on its terrestrial acidification, eutrophication strength, and ecotoxicity of the environment and the ecosystem at large.

Despite the plethora of studies, little attention is paid to the relationship between EFP, economic growth, and urbanization in Nigeria. Given the rate of urbanization in Nigeria, this kind of study is necessary to provide an empirical insight on the issue. Few studies that considered the Nigerian case have numerous methodological flaws (in terms of estimation technique, the proxy for environmental degradation, ignoring structural breaks, etc.) that are addressed in this current study. The study is outlined as follows: the "Literature review" section presents a review of related literature. The "Material and method" section explains the methodological procedures employed. The results are discussed in the "Findings and discussion of results" section. The "Conclusion and policy directions" section concludes with policy directions (Liddle and Messinis 2015; Nathaniel 2019).

Literature review

The literature presents theories that link foreign direct investment (FDI) to environmental degradation/wellness. A situation where FDI drives environmental degradation explains the pollution haven hypothesis (PHH). On the flip side, a situation where FDI mitigates environmental degradation explains the pollution halo hypothesis. Several studies have been motivated by the PHH. Most of the initial studies on the PHH focused on establishing whether environmental regulation is a precursor for FDI flows (see Shen et al. 2017; Xie et al. 2017). Destek and Sinha (2020) used the mean group and Common Correlated Mean Group (CCEMG) estimator to investigate the impact of trade and economic growth on the EFP in 24 OECD countries between 1980 and 2014. From their findings, both variables reduce the EFP. Nathaniel et al. (2020a) applied the Augmented Mean Group (AMG) estimator alongside the mean group and CCEMG to explore the impact of urbanization, energy consumption, and economic growth on the EFP in MENA countries from 1990 to 2016. They discovered that economic growth and urbanization increase the EFP, and a unidirectional causality also flows from both variables to the EFP.

In a similar vein, Nathaniel et al. (2020b) used the AMG estimator to explore the effects of trade, urbanization, and economic growth on the EFP in CIVETS (Colombia, Indonesia, Vietnam, Egypt, Turkey, and South Africa). They reported that trade and economic growth do not harm the environment. On the flipside, urbanization and energy consumption increase the EFP. Furthermore, Nathaniel et al. (2020c) used the quantile regression method to examine the impact of urbanization, FDI, and economic growth on the EFP in coastal Mediterranean countries. They discovered that the three variables add to environmental quality by reducing the EFP. However, they further discovered that the PHH does not hold for the examined region. Zafar et al. (2019) discovered that FDI reduces EFP in the USA.

Balogh and Jámbor (2017) included tourist arrival and industrial structure as explanatory variables to analyze the determinants of carbon emissions in 168 countries. Tourist arrival, agricultural land productivity, and trade encourage emissions while agricultural development reduces emissions. Wang et al. (2016) probed further the urbanization-CO_2 emissions nexus for the BRICS countries from 1985 to 2014. Empirical results clearly indicated that urbanization drives CO_2 emissions. Also, they discovered that urbanization leads to more CO_2 emissions. Chin et al. (2018) examined the determinants of CO_2 emissions in Malaysia using a decomposition-type threshold method. Growth in the economy was the major determinant of CO_2 emissions amidst other variables in the model. The authors call for green growth in order to enhance environmental sustainability in Malaysia. Ameyaw and Yao (2018) investigated the impact of GDP on carbon emission in five countries in Africa within the period 2007 to 2014. The study revealed no form of causality between the gross fixed capital formation and CO_2 emissions. To reduce CO_2 emissions, the authors suggested a shift to alternative energy sources with lower greenhouse gas emission.

Zhu et al. (2018) examined the link between urbanization, income inequality, and CO_2 emissions in the BRICS countries. Income inequality increases CO_2 emissions, while urbanization reduces it. Daramola and Eziyi (2010) are among the very few studies that explored urban environmental problems in Nigeria relying on archival records and observations. Rapid urbanization, colonial antecedents of Nigerian cities, and psychological orientation of residence were highlighted as factors hindering sustainable development in Nigeria. Ahmed et al. (2020b) explored the influence of urbanization and economic growth on the EF in China while controlling for natural resource abundance. Their findings showed that natural resource, urbanization, and economic growth increase the EF. Ahmed et al. (2020a) had earlier reported a similar result for the G7 countries. Danish et al. (2020) used the FMOLS and DOLS techniques to show that urbanization reduces the EF in BRICS.

Kwakwa et al. (2018) investigated the effects of natural resources extraction and urbanization for environmental quality in Ghana. Findings showed that urbanization and natural resources encourage carbon emission thereby reducing environmental quality in Ghana. Ali et al. (2017) explored the urbanization-CO_2 emissions nexus in Singapore. The ARDL result revealed a negative relationship between both variables. This suggests that urbanization improves the environment in Singapore by reducing CO_2 emissions. This discovery is in consonance with the study of Raggad (2018) for Saudi Arabia. Similarly, Saidi and Mbarek (2017) discovered that financial development and urbanization promote environmental quality, while income performs the exact opposite in nineteen countries from 1990 to 2013.

There are also a few studies that adopted EFP instead of CO_2 emissions as a measure for environmental quality. Al-mulali and Ozturk (2015) also used FMOLS to examine the determinants of EFP in 14 MENA countries. From their findings, urbanization degrades the environment while political stability improves it. Nathaniel et al. (2019) investigated the effect of urbanization and energy consumption on EFP in South Africa from 1965 to 2014. They discovered that economic growth deteriorates the environment while urbanization performs the opposite. Saint Akadiri et al. (2019) carried out a trivariate study encompassing energy consumption, EFP, and growth in South Africa from 1973 to 2014. In line with the studies of Nathaniel et al. (2019), they discovered the deteriorating impact of economic growth on EFP in South Africa. Bello et al. (2018) explored the impact of electricity on four environmental indicators (EFP inclusive) in Malaysia. Their findings suggest that urbanization and hydroelectricity exact no harmful impact on the environment, but rather drive growth. Solarin and Al-Mulali (2018) examined the impact of FDI on three environmental indicators (CO_2, EFP, and carbon footprint) for twenty countries using the AMG algorithm. The result showed that FDI exacts no influence on the three indicators, while urbanization, GDP, and energy consumption drive environmental degradation. Destek and Sarkodie (2020) used the same methodology (AMG) and reported that energy consumption is culpable for an increase in EFP from 1977 to 2013 for eleven industrialized countries. This supports the recent discovery of Baloch et al. (2019) who discovered that urbanization and GDP add to EFP in fifty-nine Belt and Road countries. Hassan et al. (2019) provided evidence to the fact that human capital and biocapacity increase EFP, while economic growth reduces EFP by about 60% in Pakistan.

Material and method

Study area

The study area will be Nigeria. Nigeria has a land mass of 923,769 km^2 that is made up of 990,890 km^2 of land and 13,879 km^2 of water. The country sits between 3° and 14° East longitude and 4° and 14° North latitude.

Data and data source

The data spans 1977–2016. The time period was sorely based on data availability. Data on EFP were derived from the Global Footprint Network (2019). The remaining data were obtained from the World Development Indicators (2019).

Analytical framework

Regression analysis

The Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model was used to explore the influence of urbanization and economic growth on EFP in Nigeria. Before the advent of the STIRPAT, Ehrlich and Holdren (1971), in their ecological model (*IPAT*), noted that environmental impact (I) is associated with population (P), affluence(A), and technology (T). In order to demonstrate the effects of factors on the environment in the IPAT model, one of the factors is allowed to change while the other two are kept constant. This suggests the proportional estimation of each of the variables on the environment.

The basic form of the model (STIRPAT) is specified as:

$$I_t = \gamma_o P_t^{\beta 1} A_t^{\beta 2} T_t^{\beta 3} \mu_t \quad (1)$$

where I measures environmental degradation, P is the population, A is the affluence, and T is the technology. The $\beta' s$ and μ are the parameter estimates and the error term respectively. In this study, environmental degradation is measured by EFP. GDP captures affluence. Our demographic variable (P) is urbanization. The T can actually be decomposed into various variables depending on the focus of the researcher (Bello et al. 2018). In this case, trade openness was adopted. The rationale for the inclusion hinges on the fact that trade openness transfer technological innovation (diffusion) from developed economies to either emerging economies or less developed (LDCs) economies. Technological innovation aids in reducing energy pollutants and also accelerates economic activities. Also, trade openness may have a negative impact as a result of dumping activities from the developed economies who see LDCs as pollution haven. We further augment the model with the inclusion of FDI.

In line with the theoretical framework of this study, the expanded model to be estimated, in its functional form, is specified as:

$$\mathrm{EFP}_t = f\left(\gamma_o U_t^{\beta 1} Y_t^{\beta 2} TO_t^{\beta 3} FDI_t^{\beta 4} \mu_t\right) \quad (2)$$

The variables were further divided by population in order to express them in per-capita term.

$$\mathrm{efp}_t = \gamma_1 u_t^{\beta 1} y_t^{\beta 2} to_t^{\beta 3} fdi_t^{\beta 4} \mu_t \quad (3)$$

The lower-case letters *efp*, u, y, *to*, and *fdi* are the per-capita terms of each of the variables. By taking the logs of each of the variables, the linearized model is shown in Eq. 4.

$$lnefp_t = \beta_0 + \beta_1 lnu_t + \beta_2 lny_t + \beta_3 lnto_t + \beta_4 lnfdi_t + \mu_t \quad (4)$$

efp is the ecological footprint (global hectares per capita), *fdi* is the foreign direct investment, y is the GDP per capita (in constant 2010 USD), u is the urbanization (percentage of the total population), and to is the trade (% of GDP).

Unit root test

In order to circumvent this problem and arrive at a more efficient and robust estimate, this study relied on Ng-Perron and ZA tests. The ZA test models are given as

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \theta Y_{t-1} + \gamma DU_t + \sum_{i=0}^{k} \xi_i \Delta Y_{t-i} + \varepsilon_t \quad (5)$$

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \theta Y_{t-1} + \phi DT_t + \sum_{i=0}^{k} \xi_i \Delta Y_{t-i} + \varepsilon_t \quad (6)$$

$$\Delta Y_t = \alpha_1 + \alpha_2 t + \theta Y_{t-1} + \gamma DU_t + \phi DT_t + \sum_{i=0}^{k} \xi_i \Delta Y_{t-i} + \varepsilon_t \quad (7)$$

DU_t shows shift at each point of a possible break at either intercept, trend, or both.

Cointegration test

We adopted the Bayer and Hanck (2013) test given the strength it draws from the combination of various individual test statistics premised on Boswijk (1995), Engle and Granger (1987), Banerjee et al. (1998), and Johansen (1991) cointegration tests. The equation is represented as:

$$EG\text{–}JOH = -2[\ln(\rho_{EG}) + (\rho_{JOH})] \quad (8)$$

$$EG\text{–}JOH\text{–}BO\text{–}BDM = -2\left[\ln\left(\left(\rho_{EG}\right) + (\rho_{JOH}) + (\rho_{BO}) + (\rho_{BDM})\right]\right. \quad (9)$$

ρ_{BDM}, ρ_{BO}, ρ_{JOH}, and ρ_{EG} are the probability values.

Estimation technique

The present study complemented the standard ARDL with the novel dynamic simulation ARDL advanced by Jordan and Philips (2018). The dynamic simulation ARDL is unique in terms of being able to capture and automatically predict the counterfactual responses in one explained variable on another explanatory variable while holding other regressors constant. To apply both techniques, the dependent variables need to be integrated of order one which our current study satisfy. In the present study, the DARDL algorithms are applied for five covariates. The graphical representation was rendered to depict the counterfactual responses on each explanatory variables on the dependent variable over the study time frame. The general form of the model is presented in Eq. 10 as:

$$\Delta Y = \mu_0 + \mu_1 t + \lambda_1 y_{t-1} + \sum_{i=1}^{n} \theta_1 v_{it-1} + \sum_{j=1}^{p} \gamma_j \Delta Y_{t-j} + \sum_{i=1}^{N}\sum_{j=1}^{P} \omega_{ij} \Delta V_{it-j} + \Psi D_t + \varepsilon_t \quad (10)$$

where V_t denotes vector; D_t captures structural breaks. Δ represents the first difference operator. N and P denote the number of observations and lag length respectively. The UECM version of the test is specified in Eq. 11 to Eq. 15.

$$\begin{aligned}\Delta lnefp = {} & \omega_1 + \omega_{dum} dum + \omega_E lnefp + \omega_F lnfdi_{t-1} \\ & + \omega_Y lny_{t-1} + \omega_U lnu_{t-1} + \omega_T lnto_{t-1} \\ & + \textstyle\sum_{i=1}^{p} \beta_i \Delta lnefp_{t-i} + \sum_{j=0}^{q} \beta_j \Delta lnfdi_{t-j} \\ & + \textstyle\sum_{k=0}^{r} \beta_k \Delta lny + \sum_{l=0}^{s} \beta_l \Delta lnu_{t-l} \\ & + \textstyle\sum_{m=0}^{t} \beta_m \Delta lnto_{t-m} + \mu_t \end{aligned} \quad (11)$$

$$\begin{aligned}\Delta lnfdi = {} & \omega_1 + \omega_{dum} dum + \omega_F lnfdi_{t-1} + \omega_E lnefp_{t-1} \\ & + \omega_Y lny_{t-1} + \omega_U lnu_{t-1} + \omega_T lnto_{t-1} \\ & + \textstyle\sum_{i=1}^{p} \beta_j \Delta lnfdi_{t-i} + \sum_{j=0}^{q} \beta_i \Delta lnefp_{t-j} \\ & + \textstyle\sum_{k=0}^{r} \beta_k \Delta lny_{t-k} + \sum_{l=0}^{s} \beta_l \Delta lnu_{t-l} \\ & + \textstyle\sum_{m=0}^{t} \beta_m \Delta lnto_{t-m} + \mu_t \end{aligned} \quad (12)$$

$$\begin{aligned}\Delta lny = {} & \omega_1 + \omega_{dum} dum + \omega_Y lny_{t-1} + \omega_E lnefp_{t-1} \\ & + \omega_F lnfdi_{t-1} + \omega_U lnu_{t-1} + \omega_T lnto_{t-1} \\ & + \textstyle\sum_{i=1}^{p} \beta_k \Delta lny_{t-i} + \sum_{j=0}^{q} \beta_i \Delta lnefp_{t-j} \\ & + \textstyle\sum_{k=0}^{r} \beta_j \Delta lnfdi_{t-k} + \sum_{l=0}^{s} \beta_l \Delta lnu_{t-l} \\ & + \textstyle\sum_{m=0}^{t} \beta_m \Delta lnto_{t-m} + \mu_t \end{aligned} \quad (13)$$

$$\begin{aligned}\Delta lnu = {} & \omega_1 + \omega_{dum} dum + \omega_U lnu_{t-1} + \omega_E lnefp_{t-1} \\ & + \omega_F lnfdi_{t-1} + \omega_Y lny_{t-1} + \omega_T lnto_{t-1} \\ & + \textstyle\sum_{i=1}^{p} \beta_l \Delta lnu_{t-i} + \sum_{j=0}^{q} \beta_i \Delta lnefp_{t-j} \\ & + \textstyle\sum_{k=0}^{r} \beta_j \Delta lnfdi_{t-k} + \sum_{l=0}^{s} \beta_k \Delta lny_{t-l} \\ & + \textstyle\sum_{m=0}^{t} \beta_m \Delta lnto_{t-m} + \mu_t \end{aligned} \quad (14)$$

$$\begin{aligned}\Delta lnto = {} & \omega_1 + \omega_{dum} dum + \omega_T lnto_{t-1} + \omega_E lnefp_{t-1} \\ & + \omega_F lnfdi_{t-1} + \omega_Y lny_{t-1} + \omega_U lnu_{t-1} \\ & + \textstyle\sum_{i=1}^{p} \beta_m \Delta lnto_{t-i} + \sum_{j=0}^{q} \beta_i \Delta lnefp_{t-j} \\ & + \textstyle\sum_{k=0}^{r} \beta_j \Delta lnfdi_{t-k} + \sum_{l=0}^{s} \beta_k \Delta lny_{t-l} \\ & + \textstyle\sum_{m=0}^{t} \beta_l \Delta lnu_{t-m} + \mu_t \end{aligned} \quad (15)$$

The F-statistic, which is based on the following hypotheses, $H_0 : \omega_E = \omega_F = \omega_Y = \omega_U = \omega_{TO} = 0$ against

$H_1: \omega_E \neq \omega_F \neq \omega_Y \neq \omega_U \neq \omega_{TO} \neq 0$, provides information on the existence of cointegration. All data, apart from EFP, were retrieved from the World Development Indicators (WDI, 2019). The data on EFP were obtained from the Global Footprint Network (2019).

Causality test

The vector error correction (VECM) approach is the most appropriate technique when variables are $I(1)$ (see Engle and Granger 1987). The equation for the test is given below as:

$$(1-L)\begin{bmatrix} LnEFP_t \\ LnU_t \\ LnFDI_t \\ LnY_t \\ LnTO_t \end{bmatrix} = \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} \beta_{11i}\beta_{12i}\beta_{13i}\beta_{14i}\beta_{15i}\beta_{16i} \\ \beta_{21i}\beta_{22i}\beta_{23i}\beta_{24i}\beta_{25i}\beta_{16i} \\ \beta_{31i}\beta_{32i}\beta_{33i}\beta_{34i}\beta_{35i}\beta_{16i} \\ \beta_{41i}\beta_{42i}\beta_{43i}\beta_{44i}\beta_{45i}\beta_{46i} \\ \beta_{51i}\beta_{52i}\beta_{53i}\beta_{54i}\beta_{55i}\beta_{56i} \end{bmatrix} \times \begin{bmatrix} LnEFP_{t-1} \\ LnU_{t-1} \\ LnFDI_{t-1} \\ LnY_{t-1} \\ LnTO_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{t1} \\ \varepsilon_{t2} \\ \varepsilon_{t3} \\ \varepsilon_{t4} \\ \varepsilon_{t5} \end{bmatrix} \quad (16)$$

where $(1-L)$ represents the difference operator, and ECT_{t-1} is the lagged error correction term. ε_{it} is the stochastic term. T-statistic for ECT_{t-1} and the F-statistics of the lagged variables show long- and short-run causality respectively.

Findings and discussion of results

The plots of the series provide evidence that each of the variables does not evolve around zero, but other means. The plots also exposed the signs of structural breaks which we capture in this study. Above all, EFP, trade, and financial development showed a high degree of fluctuation throughout the time period (Fig. 1).

Descriptive statistics

From the results in Table 1, GDP has the highest average. All the variables, apart from urbanization, are positively skewed. They are also platykurtic and normally distributed as revealed by their kurtosis and probability values respectively.

FDI and y are positively associated with EFP. Trade and urbanization are negatively correlated with EFP and y and positively correlated with FDI.

Unit root

Table 2 and Table 3 present the unit root tests (ZA, ADF, PP, and Ng-Perron). The importance of these tests is underscored by the fact that it determines the estimation technique.

All the tests are in harmony. They affirmed that all the variables are $I(1)$. Since there is no $I(2)$ variable(s), we can proceed with the cointegration tests as well as the ARDL estimation technique.

The bounds test result in Table 4 is in support of a long-run interaction among the variables as the F-statistic value of 6.841 is greater than the 5% (upper bound) critical value of 5.304.

Table 5 shows the Bayer and Hanck combined cointegration test results. The Fisher statistic for EG − JOH − BO − BDM and EG − JOH is greater than the 5% critical values. This further shows that cointegration exists. This complements the findings in Table 4 above.

The results in Table 6 revealed that economic growth adds to environmental deterioration in Nigeria, at least, in the short run. Just like other emerging economies, growth at its initial stage may not be healthy for the environment. This is the intuition behind the EKC hypothesis. This finding is in consonance with the results of Mikayilov et al. (2018) for Azerbaijan, Nathaniel et al. (2019) for South Africa, Khan et al. (2019) for Pakistan, Zhang and Da (2015) for China, Alshehry and Belloumi (2017) for Saudi Arabia, and Bélaïd and Youssef (2017) and Amri (2017) for Algeria. Yeh and Liao (2017) discovered the opposite for Taiwan. They further concluded that Taiwan has developed to a stage were economic forces have no detrimental effects on the environment. These discrepancies in result could, however, be due to the differences in the level of development between Nigeria and Taiwan. Again, the different proxies used for environmental degradation could have prompted these variations.

Just like economic growth, FDI and trade add 0.03% and 0.04% respectively to environmental degradation in Nigeria by increasing EFP, while urbanization performance shows the opposite. These findings are particularly worrisome since the inflow of FDI and the country's trade relations with the outside world have been increasing steadily over the years. This implies that Nigeria has to trade off growth for an improvement in environmental quality. This might not be an ideal situation since the country needs both growth and an improved environment. Again, Nigeria's growth largely depends on the energy sector which makes her highly susceptible to shocks (positive and negative) in the global oil price.

Worst still, the energy it produced and consume is largely non-renewable. Nigeria can adjust its energy portfolio by concentrating on energy sources that are "clean" and have the tendencies to promote growth (Bhattacharya et al. 2016;

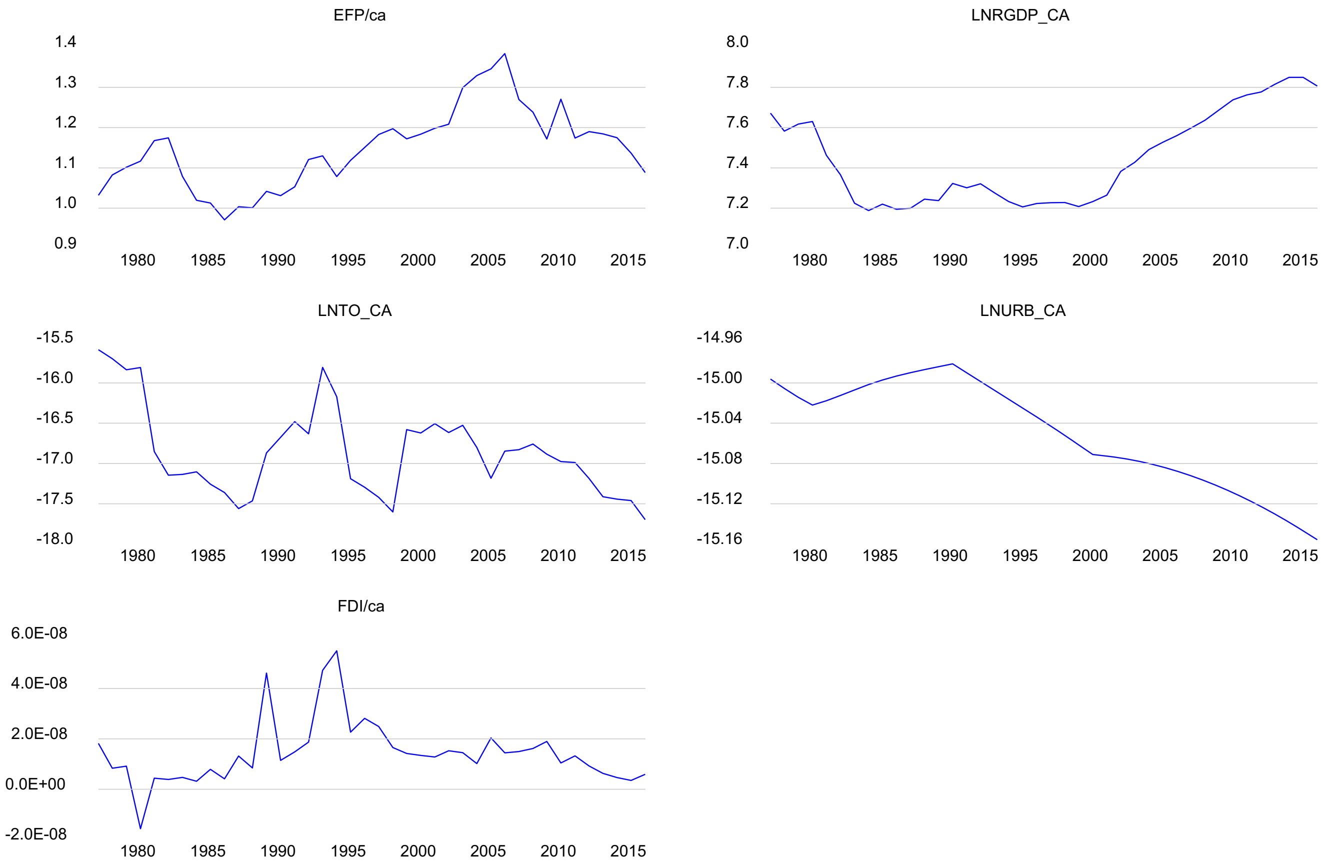

Fig. 1 Plots of the variables. Sources: author's compilation

Bölük and Mert 2015) without harming the environment (Emir and Bekun 2019; Bekun et al. 2019; Apergis et al. 2018). In the long run, economic growth and urbanization reduce environmental degradation. This is consistent with the findings of Jebli and Belloumi (2017) for Tunisia. However, FDI and trade maintained a consistent result

Table 1 Descriptive statistics and correlation analysis

	lnefp	*lnfdi*	*lny*	*lnto*	*lnu*
Mean	0.133	− 18.25	7.444	− 16.85	− 15.04
Median	0.147	− 18.14	7.374	− 16.87	− 15.03
Maximum	0.324	− 16.71	7.849	− 15.58	− 14.98
Minimum	− 0.029	− 19.57	7.188	− 17.69	− 15.15
Std. dev.	0.085	0.708	0.226	0.554	0.052
Skewness	0.164	0.049	0.435	0.715	− 0.402
Kurtosis	2.520	2.674	1.689	2.791	1.876
Jarque-Bera	0.563	0.188	4.129	3.489	3.184
Probability	0.754	0.910	0.126	0.174	0.203
Correlation					
lnefp	1				
lnfdi	0.153	1			
lny	0.379	− 0.288	1		
lnto	− 0.006	0.374	− 0.015	1	
lnu	− 0.649	0.175	− 0.751	0.320	1

Sources: author's compilation

Table 2 Unit root results

Variables	ADF	PP	ZA	Break date
	T-statistic	T-statistic	T-statistic	Time break
Panel A				
AT levels				
*ln*y	− 2.438	− 2.349	− 2.475	1994
*ln*fdi	− 1.498	− 2.655	− 3.246	1993
*ln*efp	− 1.283	− 1.510	− 2.823	2003
*ln*u	− 1.201	− 1.233	− 3.841	1991
*ln*to	− 2.706	− 2.706	− 3.516	1989
Panel B				
AT first difference				
*ln*y	− 4.207**	− 4.239***	− 5.150**	1988
*ln*fdi	− 10.755***	− 10.45***	− 8.145***	1995
*ln*efp	− 6.006***	− 6.005***	− 6.739***	2000
*ln*u	− 3.5841**	− 3.655**	− 4.915**	1984
*ln*to	− 5.639***	− 5.640***	− 9.478***	1985

*** and ** represent 0.01% and 0.05% significance levels respectively

Source: authors' computation

Table 3 Ng-Perron unit root (unit root without break)

Variable	At levels		At first difference	
	Mza	Mzt	Mza	Mzt
*ln*efp	− 3.1653	− 1.8599	− 16.7767***	− 6.1409***
*ln*u	− 5.1382	− 2.7769	− 10.0836***	− 14.9684***
*ln*y	− 3.1653	− 1.1723	− 16.7768**	− 6.2271**
*ln*fdi	− 4.0228	− 1.3711	− 14.4246**	− 6.4251***
*ln*to	− 7.9337	− 1.9792	− 18.9570**	− 4.8703***

*** and ** represent 0.01% and 0.05% significance levels respectively

Source: authors' computation

with their short-run findings. Both variables exacted a more detrimental impact on the environment in the long run. Suffice to say that the country's trade has not been "green." Since trade deteriorates the environment, utmost diligence should be the watch-word when it comes to trade expansion. The desire to expand trade can give way to the importation of products that are not environmentally friendly. This is very possible in developing countries (Nigeria inclusive) with weak institutions.

In the DARDL results, the coefficient of FDI is positive in both time horizons. This aligns with the PHH, where LDCs are considered dumping ground for FDI inflows. This is consistent with the study of Magazzino et al. (2020) for China, thus the need for the Nigeria government to regulate the flow of FDI as it can influence environmental sustainability. This result is consistent with the outcomes of the standard ARDL (see Table 7). Similarly, a positive and statistically significant relationship exists between EFP and trade openness, except for lag (− 1) which align with the already-established sign of the standard ARDL output. However, interestingly, we observed an inverse relationship between urbanization and EFP. That is, urbanization helps to increase the quality of the environment in the long run. This aligns with the avocation of United Nation Sustainable Development Goal 13.

Interpretation of the impulse response

We further graphically exposit the impose responses of each of the variables on the other. Accordingly, Figures 2, 3, 4, 5, and 6 depict the impulse responses among the variables for each of the five fitted model respectively. Figure 2a–d depict the response of EFP to ± 10% change (shock) in FDI, GDP, and trade openness and urbanization at 30th scenario time. Figure 2a, c, and d reveal that positive shock on FDI, trade openness, and urbanization increase the EFP while negative shock on the variables reduces the EFP respectively. This suggests that trade openness and FDI intensify ecological demand. This occurs because foreign firms may not adopt "clean" technology for production, and hence consequently contributes to environmental damage. Similarly, urbanization increases the demand for resources to provide sanitation, road infrastructure, drainage systems, and portable water in the urban areas. This increases the EFP and contributes to environmental degradation. On the other hand, Fig. 2 b shows that positive shock in GDP leads to a decline in EFP while negative shock increases EFP. This affirms that increase in real income in Nigeria propels the demand for quality environment and thus decreases environment degradation. Meanwhile, the figures further

Table 4 Results of bounds test

Estimated model	Optimal lag length	Break year	Diagnostic tests		
			F-stat.	Normal	ARCH
*ln*efp = *f*(*ln*fdi, *ln*y, *ln*to, *ln*u)	(4, 3, 2, 3, 4)	2003	6.841**	2.823	0.780
*ln*fdi = *f*(*lefp*, *ln*y, *ln*to, *ln*u)	(4, 4, 0, 4, 4)	1993	8.718***	0.054	0.545
*ln*u = *f*(*ln*efp, *ln*fdi, *ln*y, *ln*to)	(4, 3, 3, 4, 2)	1991	13.49***	0.975	0.814
*ln*to = *f*(*ln*efp, *ln*fdi, *ln*y, *ln*u)	(4, 5, 5, 4, 5)	1989	15.44***	0.591	0.130
*ln*y = *f*(*ln*efp, *ln*fdi, *ln*to, *ln*u)	(2, 2, 4, 3, 3)	1994	11.93***	1.101	0.620
	Critical value bounds (finite sample)				
Significance level (%)	Lower bound	Upper bound			
10	3.374	4.512			
5	4.036	5.304			
1	5.604	7.172			

*** and ** represent 0.01% and 0.05% significance levels respectively

Source: authors' computation

Table 5 The result of Bayer-Hanck test

Estimated model	EG-JOH	EG-JOH-BO-BDM	Cointegration
*ln*efp = *f*(*ln*fdi, *ln*y, *ln*to, *ln*u)	11.09	20.69**	Yes
*ln*fdi = *f*(*ln*efp,*ln*y, *ln*to, *ln*u)	16.56**	27.02**	Yes
*ln*u = *f*(*ln*efp, *ln*fdi, *ln*t, *ln*to)	16.34**	34.78**	Yes
*ln*to = *f*(*ln*efp, *ln*fdi, *ln*y, *ln*u)	12.43**	27.77**	Yes
*ln*y = *f*(*ln*efp, *ln*fdi, *ln*to, *ln*u)	11.05**	21.18**	Yes
5% critical value	10.576	20.143	

*** and ** represent 0.01% and 0.05% significance levels respectively

Source: authors' computation

show that the effects of the shocks in all the variables on EFP stabilize in the long run. These findings conform to the previous studies of Sarkodie et al. (2019) and Baloch et al. (2019).

Moreover, the impulse response for the model in which FDI is the dependent variable is displayed in Fig. 3a–d. Figure 3a and c depict that positive (negative) shocks on EFP and trade openness are associated with increases

Table 6 ARDL results

Dependent variable: (*lnefp*)				
Variable	Coefficient	standard error	*t*-Statistic	*P* value
Short-run estimates				
Constant	− 76.673	14.395	− 5.3262	0.0002
D(*ln*efp(− 2))	0.6897	0.1318	5.2318	0.0002
D(*ln*fdi)	0.0304	0.0100	3.0186	0.0107
D(*ln*fdi(− 1))	0.0526	0.0143	3.6828	0.0031
D(*ln*fdi(− 2))	0.0562	0.0130	4.2999	0.0010
D(*ln*y)	1.2481	0.1845	6.7626	0.0000
D(*ln*to)	0.0427	0.0151	2.8131	0.0157
D(*ln*to(− 1))	− 0.0777	0.0136	− 5.6768	0.0001
D(*ln*u)	− 13.670	3.1839	− 4.2935	0.0010
D(*ln*u(− 1))	− 11.297	2.7801	− 4.0635	0.0016
D(*ln*u(− 2))	14.445	2.6147	5.5245	0.0001
D(D2003)	0.0123	0.0250	0.4909	0.6323
ecm(− 1)	− 0.8154	0.15301	− 5.3288	0.0002
Long-run estimates				
*Ln*fdi	0.0361	0.0401	0.8997	0.3860
*Ln*y	− 0.2097	0.1667	− 1.2580	0.2323
*Ln*to	0.0471	0.0233	2.0170	0.0666
*Ln*u	− 6.4926	2.2778	− 2.8503	0.0146
D2003	0.0819	0.0782	1.0467	0.3158
R-squared	0.9722			
F-statistic	21.014			
Diagnostic tests				
Test	Statistics	*P* value		
Normality	0.0665	0.9673		
Serial correlation	0.0256	0.9215		
ARCH	0.7398	0.7297		

Source: authors' computation

Table 7 Dynamic ARDL simulations

	(1)	(2)	(3)	(4)	(5)
Variables	ΔlnEFP	ΔlnFDI	ΔlnGDP	ΔlnTO	ΔlnURB
ΔlnEFP		3.472	0.553**	6.978*	− 0.0307**
		(0.701)	(2.973)	(2.119)	(− 2.181)
lnEFP(− 1)	− 0.787***	1.211	0.417*	7.307**	− 0.0224
	(− 4.628)	(0.244)	(2.003)	(2.316)	(− 1.474)
lnEFP(− 2)	0.598***	2.904	− 0.526***	− 3.899	0.0074
	(3.180)	(0.661)	(− 3.396)	(− 1.209)	(0.512)
lnEFP(− 3)	− 0.663***	4.039	0.485**	6.070*	− 0.0147
	(− 3.872)	(0.930)	(2.899)	(2.054)	(− 1.257)
ΔlnFDI	0.0113		− 0.00168	− 0.101	0.0018**
	(0.701)		(− 0.120)	(− 0.464)	(2.244)
lnFDI(− 1)	0.0661**	− 1.589***	− 0.0312	− 0.748*	0.0034**
	(2.283)	(− 4.000)	(− 1.113)	(− 1.823)	(2.871)
lnFDI(− 2)	0.0123	0.326	− 0.000351	− 0.163	− 0.0018**
	(0.788)	(1.238)	(− 0.0259)	(− 0.783)	(− 2.610)
lnFDI(− 3)	− 0.0610**	0.0393	0.0665***	0.639*	− 0.0030**
	(− 2.805)	(0.0804)	(4.770)	(1.962)	(− 2.260)
ΔlnGDP	0.768**	− 0.716		− 6.441	0.0516**
	(2.973)	(− 0.120)		(− 1.551)	(2.859)
lnGDP(− 1)	− 0.371	11.72***	0.184	6.899*	− 0.0295**
	(− 1.365)	(3.061)	(0.761)	(2.054)	(− 2.530)
lnGDP(− 2)	− 0.400	− 1.353	0.297	1.552	0.00780
	(− 1.663)	(− 0.291)	(1.414)	(0.438)	(0.515)
lnGDP(− 3)	0.276	− 5.214	− 0.249	− 3.410	0.00287
	(1.394)	(− 1.524)	(− 1.495)	(− 1.272)	(0.229)
ΔlnTO	0.0390*	− 0.174	− 0.0259		0.0026*
	(2.119)	(− 0.464)	(− 1.551)		(2.087)
lnTO(− 1)	− 0.0142	0.193	0.0248	− 0.147	− 0.0014
	(− 0.686)	(0.527)	(1.511)	(− 0.525)	(− 1.296)
lnTO(− 2)	0.0442*	− 0.677	− 0.0327	− 0.423	0.0044***
	(1.911)	(− 1.616)	(− 1.611)	(− 1.276)	(3.347)
lnTO(− 3)	0.0490**	0.360	− 0.0322	− 0.557*	− 0.0012
	(2.344)	(0.838)	(− 1.667)	(− 1.877)	(− 0.818)
ΔlnURB	− 9.096**	162.2**	7.762**	101.7	
	(− 2.224)	(2.284)	(2.242)	(1.753)	
lnURB (− 1)	− 15.82***	− 30.08	12.88***	140.9*	− 0.142
	(− 3.684)	(− 0.275)	(3.388)	(1.921)	(− 0.436)
lnURB (− 2)	29.17***	− 82.29	− 23.40***	− 294.5**	0.741
	(4.125)	(− 0.431)	(− 3.637)	(− 2.454)	(1.358)
lnURB (− 3)	− 9.238	90.80	9.819**	130.6*	− 0.722**
	(− 1.775)	(0.918)	(2.411)	(1.906)	(− 2.644)
Constant	− 49.73**	739.7**	18.86	587.3**	− 1.672**
	(− 2.959)	(2.293)	(1.051)	(2.425)	(− 2.973)
Observations	33	33	33	33	33
R-squared	0.878	0.835	0.899	0.718	0.971
SIMS	1000	1000	1000	1000	1000
F-stat [*P* value]	4.30[0.006]	3.03[0.0264]	5.35[0.0023]	4.67[0.008]	20.20[0.0000]

T-statistics in parentheses ( ) while *, **, and *** denote 10%, 5%, and 1% level of significance respectively

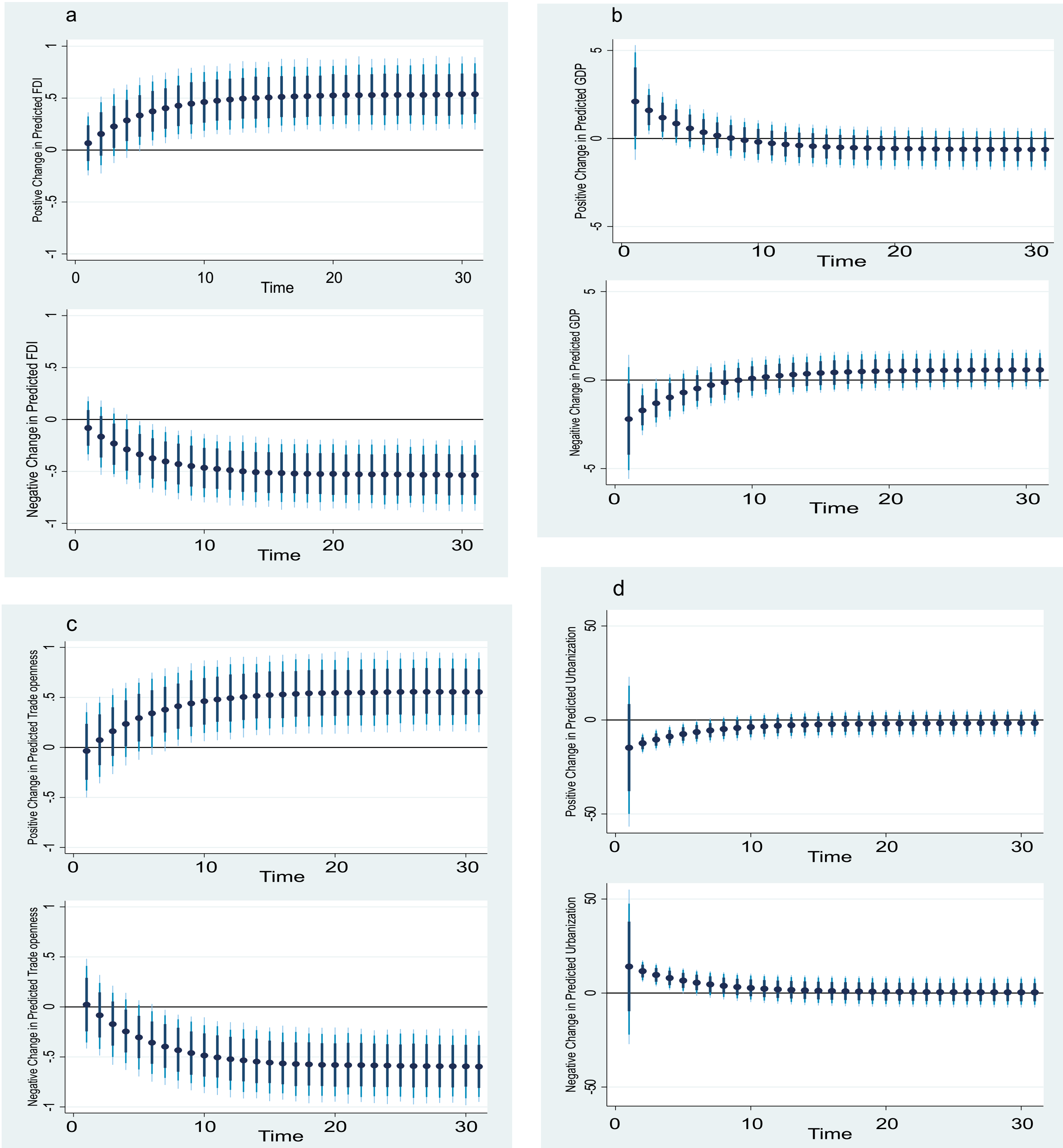

Fig. 2 Model 1 (**a**–**d**) depict ± 10% change in each variable on EFP. **a** FDI shock in EFP model. **b** GDP shock in EFP model. **c** Trade openness shock in EFP model. **d** Urbanization shock in EFP model

(decrease) in FDI respectively. Conversely, Fig. 3 b and d demonstrate that negative (positive) shocks on GDP and trade openness result to decline (increase) in FDI respectively. We presented the response of GDP to shocks in EFP, FDI, trade openness, and urbanization in Fig. 4 a–d. The graph indicates that GDP decreases (increases) explosively in response to positive (negative) shocks in EFP and urbanization respectively. On the contrary, GDP increases (decreases) explosively in response to positive (negative) shocks in FDI and trade openness respectively. In the case of the model with trade openness as the dependent variable, Fig. 5 a, c, and d demonstrate that positive shocks in EFP, GDP, and urbanization increase trade

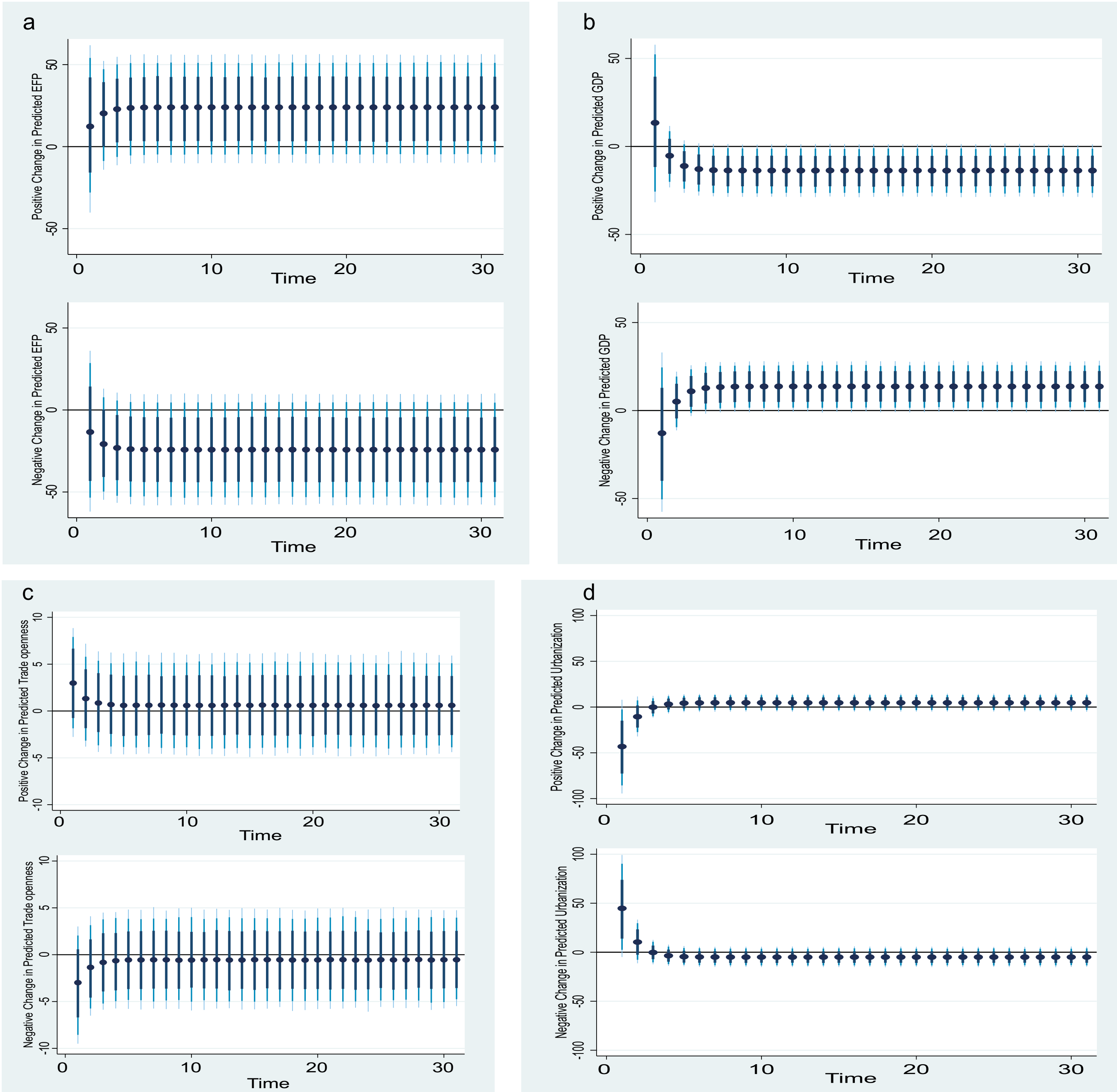

Fig. 3 Model 2 (**a**–**d**) depict ± 10% change in each variable on FDI. **a** EFP shock in FDI model. **b** GDP shock in FDI model. **c** Trade openness shock in FDI model. **d** Urbanization shock in FDI model

openness while negative shocks decline trade openness respectively. Finally, Fig. 6 a depicts that positive shock in EFP is connected with a decline in urbanization in the long run.

Identifying the direction of causality is necessary for policy direction. The causality results are reported in Table 8. We discovered a unidirectional causality from economic growth to FDI and urbanization in the short run. This shows that growth in the economy drives FDI inflow into the country. Therefore, to promote more FDI flow, the country's growth needs to be persistent and maintained. This finding is particularly appealing because, after the horrible recession that started in 2016 up to the first quarter of 2017, the Nigeria economy has witnessed a stable growth with a concomitant increase in FDI inflows.

Table 9 confirms that the chosen break dates which were informed by significant policy episodes (which could be economically or politically induced) are significant. For example, the break date (2003) is the year the general elections were held and this affected the macroeconomic structure of the country.

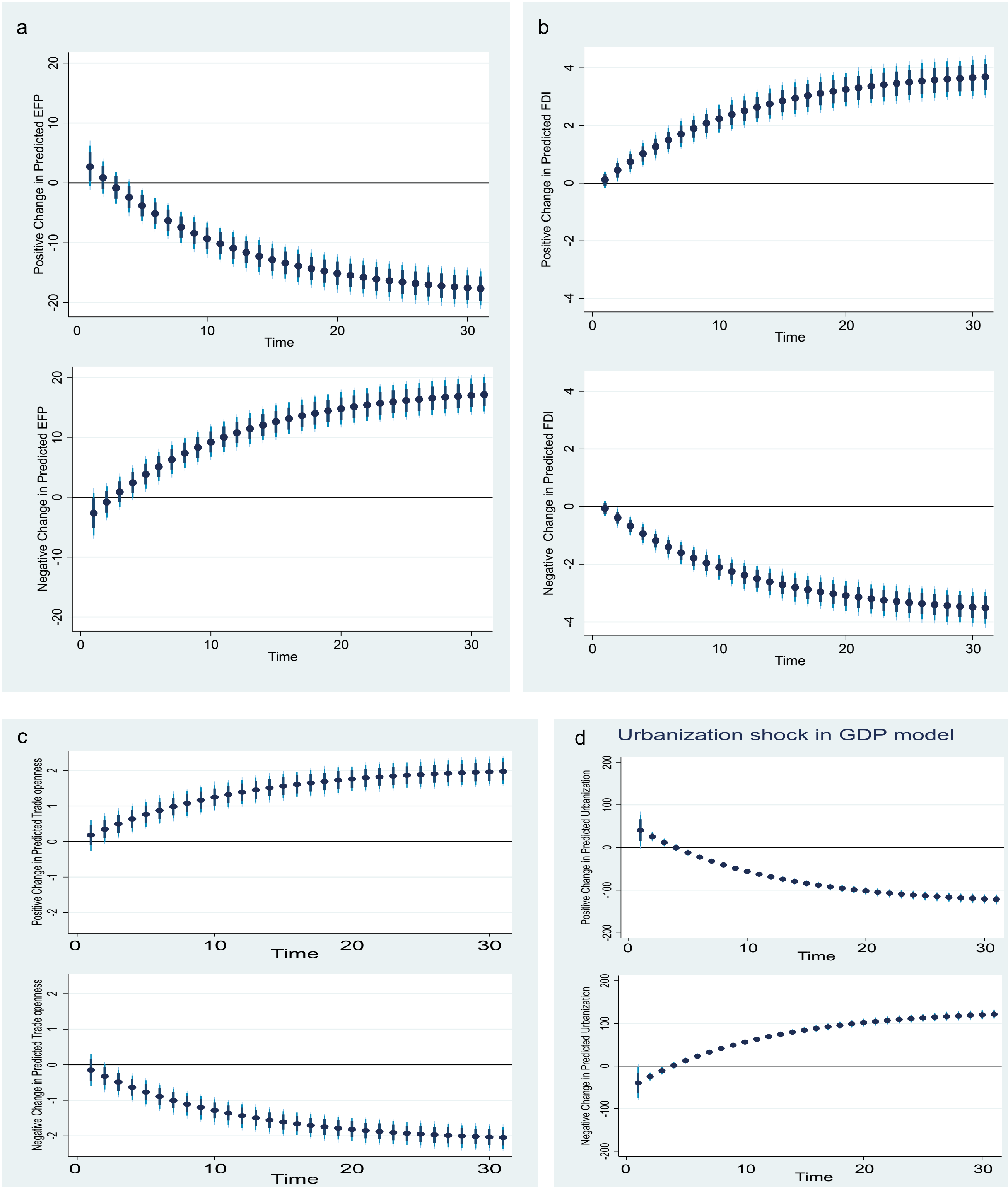

Fig. 4 Model 3 (**a**–**d**) depict ± 10% change in each variable on GDP. **a** EFP shock in GDP model. **b** FDI shock in GDP model. **c** Trade openness shock in GDP model. **d** Urbanization shock in GDP model

Conclusion and policy directions

The study explored the effects of urbanization, trade, FDI, and economic growth on EFP in Nigeria from 1977 to 2016. Apart from the traditional Augmented Dickey Fuller and Phillip Perron unit root tests, the Ng and Perron (2001) and the ZA (1992) tests were applied. We employed the ZA test and incorporated the break dates into the ARDL estimation.

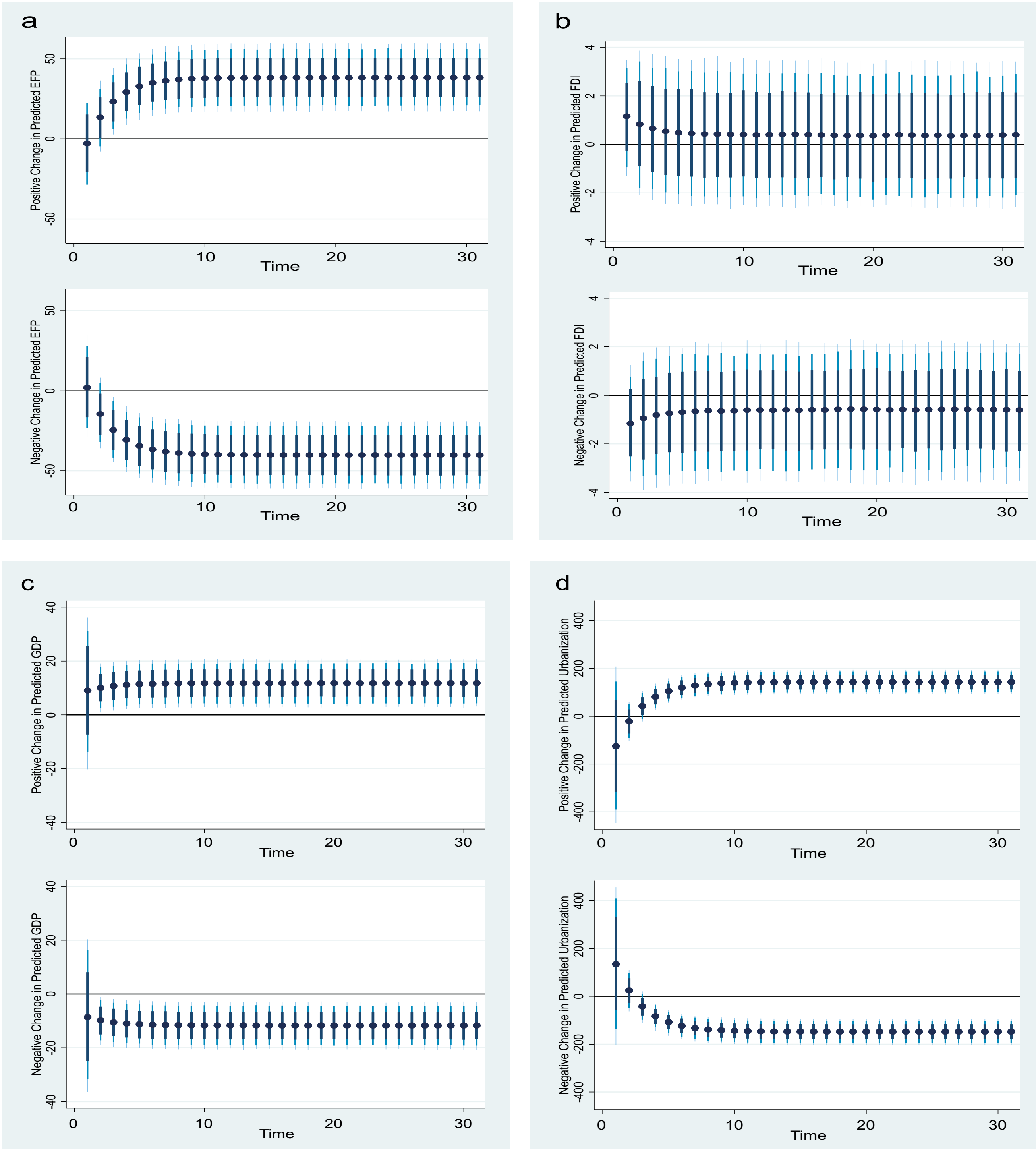

Fig. 5 Model 4 (**a**–**d**) depict ± 10% change in each variable on trade openness. **a** EFP shock in trade openness model. **b** FDI shock in trade openness model. **c** GDP shock in trade openness model. **d** Urbanization shock in trade openness model

Findings revealed that trade, FDI, and economic growth, apart from urbanization which produced a consistent result in both time periods, promote environmental degradation in the short run. FDI and trade deteriorate the environment further in the long run, while economic growth added to environmental quality. These findings were consistent with the outcome of the dynamic ARDL simulations. This calls for reasonable policy directions.

The horrendous effects of growth on the environment could be abated by investing and consuming renewables (like wind,

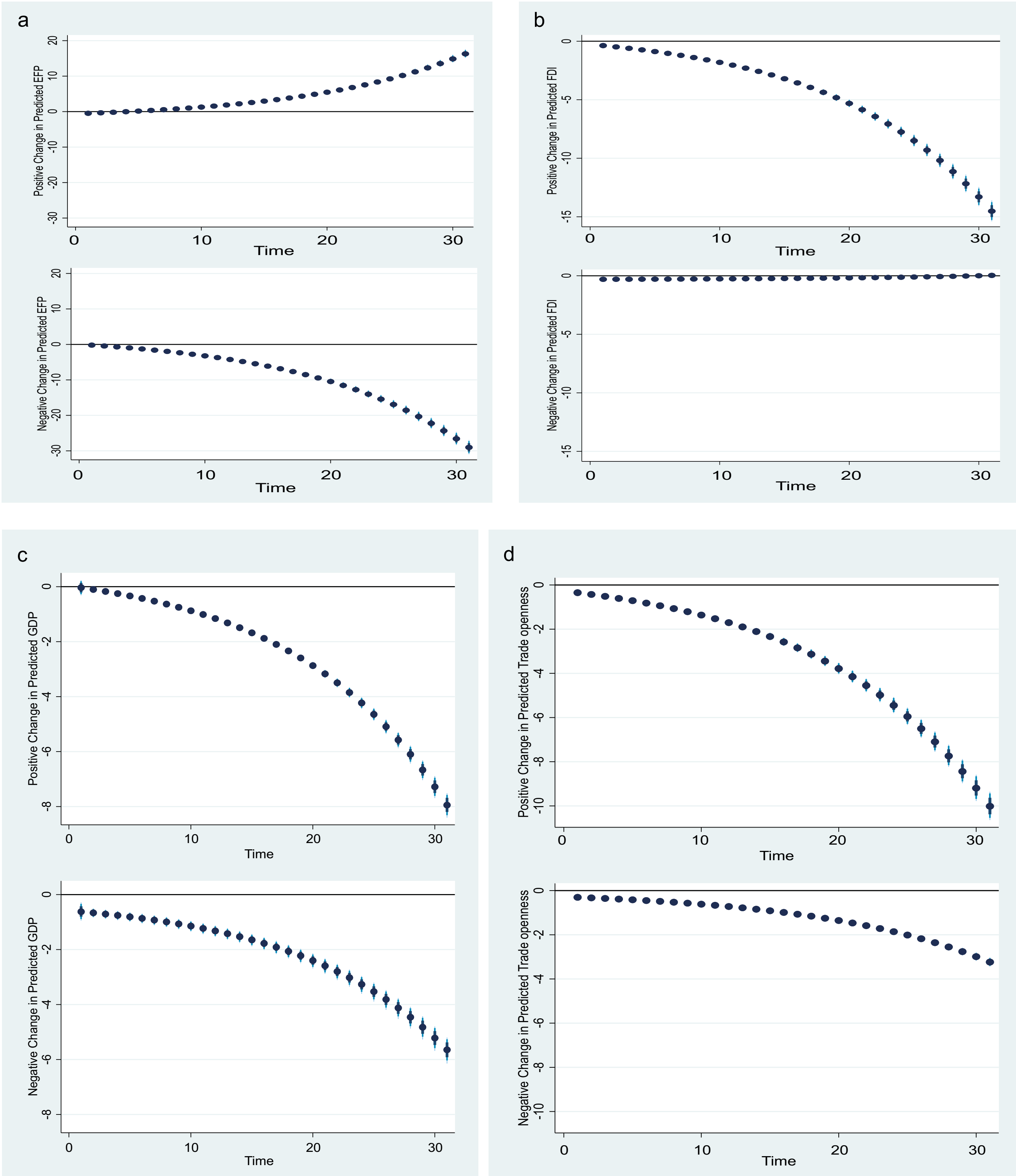

Fig. 6 Model 5 (**a**–**d**) depict ± 10% change in each variable on urbanization. **a** EFP shock in urbanization model. **b** FDI shock in urbanization model. **c** GDP shock in urbanization model. **d** trade shock in urbanization model

solar, geothermal, tidal, etc.). These energy sources are not only clean but also low in emissions. One way Nigeria can achieve sustainable growth is to invest in renewables. There is a dire need for policymakers to incentivize the use of renewables and clean production processes by foreign firms. This will stimulate the technique effect. The formulation and

Table 8 VECM causality results

Dependent variable	Direction of causality					
	Short run					Long run
	Δlnefp$_{t-i}$	Δlnfdi$_{t-i}$	Δlny$_{t-i}$	Δlnu$_{t-i}$	$\Delta ln$to$_{t-i}$	ect$_{t-i}$
Δlnefp	_	1.760	2.159	3.026	3.426	− 0.261**
		(0.195)	(0.139)	(0.069)	(0.050)	(0.015)
Δlnfdi	0.616	_	0.314	1.551	0.859	− 2.344
	(0.549)		(0.733)	(0.235)	(0.437)	(0.136)
Δlny	2.535	4.491**	_	5.451**	1.100	0.077
	(0.102)	(0.023)		(0.011)	(0.350)	(0.351)
Δlnu	0.469	5.403**	0.205	_	1.122	− 0.011**
	(0.631)	(0.012)	(0.815)		(0.343)	(0.051)
$\Delta ln$to	0.519	0.451	0.507	0.586	_	1.188
	(0.601)	(0.642)	(0.608)	(0.564)		(0.263)

Source: authors' computation

**denotes 5% significance rejection level, while ( ) are p values

strengthening of existing environmental laws for the inflow of FDI will also be helpful in curtailing economic dumping. The importation of hazardous goods could be avoided through the imposition of dumping duties which will encourage the direction of FDI to the non-polluting sectors of the economy. The country should exercise diligence in its trade dealings with the outside world. As a developing country, Nigeria imports more than it exports. The country must ensure that it engages in "*green*" trade by importing goods/technologies that are environmentally friendly. Nigeria has policies in place that checkmates the quality of its imports/trade, but these policies may not be efficient if the institutions are weak. Institutions need to be strengthened if Nigeria intends to secure her environment and attain the SDGs.

Authors' contributions SS edited and revised the manuscript. SN conceived the idea, reviewed the literature, discussed the results, and provided relevant policy recommendations/directions. FB wrote the methodology section and collected the data required for the study. KO wrote the introduction. AA analyzed the data, and interpreted the results. All authors read and approved the final manuscript.

Table 9 Chow Forecast test

Test predictions for observations from 1989 to 2016			
	Value	df	Probability
F-statistic	8.2885	(28, 6)	0.0070
Likelihood ratio	143.55	28	0.0000
Test predictions for observations from 2003 to 2016			
	Value	df	Probability
F-statistic	5.6258	(14, 20)	0.0003
Likelihood ratio	62.282	14	0.0000

Source: authors' computation

Data availability The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Compliance with ethical standards

The present study does not involve any laboratory analysis or experimentation neither involves animals.

"Not applicable"

Competing interests The authors declare that they have no competing interests.

Ethics approval and consent to participate Not applicable

Consent to participate Not applicable

Consent to publish Not applicable

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